

Patent claims

1. Method for efficiency enhancement in the transformation of heat into mechanical or electrical energy under exploitation of thermally induced phase transitions with entropy change without state of aggregation changes, characterised in that a temperature difference is maintained at both sides of a material provided for phase transformation, and a gradient-like shift of the transformation temperature for a specified operating temperature range is firmly adjusted in this material provided for phase transformation along the axis of the heat flow, and the partial segments with higher transformation temperatures are arranged linear or finely staggered at the hot side and those with lower transformation temperatures at the cold side, in order to achieve a thermal series connection of these partial segments by thermal vibration in the range of the material-conditioned hysteresis and an alternately changing phase transformation, if possible, simultaneously in all partial segments, and there is a heat recovery of non-used latent heat between the individual segments.

2. Method according to claim 1, characterised in that the phase transformation from martensitic to austenitic metal lattice structure in some metal alloys with a distinctive form change, the shape-memory effect (SME), is utilised.
3. Method according to claim 1, characterised in that the phase transformation from ferromagnetic to paramagnetic state in some metal alloys with a distinctive magneto-caloric effect (MCE) is utilised.
4. Method according to one of the above claims, characterised in that the compensation of heat is performed proportionally to the withdrawn collectible energy by means of a regulable partial flux of a liquid or gaseous heat transfer fluid that superimposes thermal vibration and flows from the hot to the cold side within one or several ducts in the material provided for phase transformation, due to which more heat transfer fluid flows through the material from the hot side to the cold side in the course of one working cycle than vice versa.
5. Method according to claim 4, characterised in that any recirculation of the partial flux from the cold side to the hot side of the material provided for phase transformation is performed as a recirculation outside of this material.

6. Apparatus for application of the method, characterised in that a tube (1) with serially lined up partial segments (1a to 1f) of metal alloys with shape-memory effect (SME), e.g. nitinol, that have different switching temperatures staggered across their length for the phase transformation between austenitic and martensitic metal structures due to different compositions or heat treatments, is coupled with a mobile mechanism that predetermines the displacement of alternately defined length or axial angular change of this tube (1) (main vibration or working stroke) and that moves a defined quantity of a heat transfer fluid (2), such as water or oil, to and fro alternately through tube (1) by means of a piston, pressure or level differences (exciter vibration).
7. Apparatus according to claim 6, characterised in that the mechanism for conveying the alternately vibrating heat transfer fluids (exciter vibration) is connected via a mass-spring system (6) to the alternately vibrating working stroke (main vibration) of tube (1) in such a manner that a temporal delay, i.e. a phase shift occurs between main and exciter vibration, while their frequencies are equal.
8. Apparatus according to claim 7, characterised in that the mass-spring vibration is performed in the resonance range.

9. Apparatus according to claims 6 to 8, characterised in that a mechanical limitation of the deformation displacement is provided for individual tube segments (1a - 1f) by means of displacement limiters, so that the potential longitudinal extension and also torsional extensions can be limited to the durably appropriate extent for the respective SME tube segments (1a - 1f).
10. Apparatus according to claims 6 to 9, characterised in that differences in the spring constant of SME tube segments (1a - 1f), transformation power and plateau stress are compensated by means of adjustable tensioning elements, such as springs and equalising masses, that are connected in parallel to the respective tube segments (1a - 1f), by adjusting an initial tension at each tube segment.
11. Apparatus according to claims 6 to 10, characterised in that parallel tightened wires, capillary tubes or spirals (coil springs) are arranged in tube (1) filled with heat transfer fluid, that are of the same SME material as the tube (1) proper, or that several SME tubes (1) filled with heat transfer fluid (2) are switched in parallel to each other.
12. Apparatus for application of the method according to claim 6, characterised by a stack of layers (1a - 1z) of soft-magnetic alloys with a

high ferromagnetic saturation magnetisation, the highest possible level of spontaneous magnetisation and each with a slightly staggered Curie temperature in the intended operating temperature range, e.g. on the basis of gadolinium with variable Si+Ge portions and/or iron-manganese with variable P+As portions, in which the heat flow is through these layers and the layers (1a, 1b, ...) with higher Curie temperatures being arranged at the hot side, those with lower Curie temperatures (... , 1y, 1z) at the cold side within the magnetic sphere of influence of a coil system (10) and are alternately or also steadily exposed to strong magnetic field (to 9), preferably to a permanent magnet (9).

13. Layers of the apparatus from claim 12, characterised in that such are formed into tubes, capillary tube bundles, ring armatures, displacement pistons, transformer sheets or supporting structures (such as motor casings or cylinder heads) or are attached to such or are executed as foam, wire-mesh or fine-fabric constructions.
14. Layers according to claim 13 of the apparatus from claim 12, characterised in that they have internal pores and ducts that have a defined permeability towards the heat flow for a liquid or gaseous heat transfer fluid.

15. Apparatus according to claim 6, characterised in that further functional layers are arranged on the surface material provided for phase transformation in the layers (1a or 1z) with layer thicknesses in the micro- or nanometre range, such catalyser, corrosion protection or thermionic acting layers (thermal diode), or that ions have been implanted into the surface.
16. Apparatus according to claim 6, characterised in that foam, wire-mesh or fine fabric constructions of non-magnetic materials serve as carrier for the soft-magnetic alloys according to 12 provided for phase transformation, that are applied as in the form of powder or granulate or are embedded as nanocomposites.
17. Apparatus according to claim 6, characterised in that further very thin layers of electrical insulating material are arranged between the layers (1a - 1z) or on the surface of the porous or fibrous metal structure of the layers (1a - 1z) and that the metallic layers (1a - 1z) are electrically wired into a plate-type capacitor.
18. Apparatus according to claim 6, characterised in that further thin layers of electrical insulating and electrical conductive material are arranged between the layers (1a - 1z) and that these layer formations in the form of capillary tubes or narrow strips are arranged like conductor loops with the electrical function of an induction coil.